1.A cutaway view of a commonly used pressure regulator is shown in the Fig.1. The desired pressure is set by turning a calibrated screw. This compresses the spring and sets up a force that opposes the upward motion of the diaphragm. The bottom side of the diaphragm is exposed to the water pressure that is to be controlled. Thus the motion of the diaphragm is an indication of the pressure difference between the desired and the actual pressures. It acts like a comparator. The valve is connected to the diaphragm and moves according to the pressure difference until it reaches a position in which the difference is zero.

(1) Sketch a block diagram showing the control system concept with the output pressure as the regulated variable. (5 %)

(2) Deriving the system equation and re-sketch the block diagram as the Laplace transformed dynamic equation (5 %)

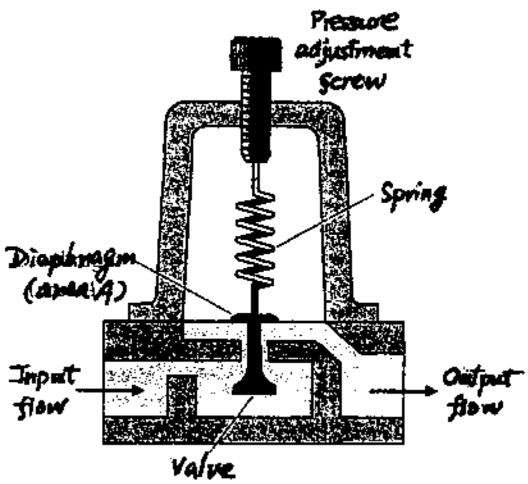


Fig. 1

2. For a paper processing plant, it is important to maintain a constant tension on the continuous sheet of paper between the wind-off and wind-up rolls. The tension varies as the widths of the rolls change, and an adjustment in the take-up motor speed is necessary, as shown in Fig.2. If the windup motor speed is uncontrolled. As the paper transfers from the windoff roll to the windup roll, the velocity v_0 decreases and the tension of the paper drops. The three roller and spring combination provides a measure of the tension of the paper. The spring force is equal to $k_1 y$, and the linear differential transformer, rectifier, and amplifier may be represented by $e_0 = -k_2 y$. Therefore the measure of the tension is described by the relation $2 T(s) = k_1 y$, where y is the deviation from the equilibrium condition. The time constant of the motor is $\tau = L_a / R_a$, and the linear velocity of the windup roll is twice the angular velocity of the motion, that is $v_0 = 2\omega_0(t)$. The equation of the motor is then

$$E_0(s) = \frac{1}{K_m}\left[\tau s \omega_0(s) + \omega_0(s)\right] + K_3 \Delta T(s)$$

where ΔT = a tension disturbance.

(a) Draw the closed loop block diagram for the system, including the disturbance $\Delta T(s)$. (5 %)

(b) Add the effect of a disturbance in the windoff roll velocity $\Delta V_1(s)$ to the block diagram. (5 %)

(c) Determine the sensitivity of the system to the motor constant K_m. (5 %)

(d) Determine the steady state error in the tension when a step disturbance in the input velocity $\Delta V_1(s) = A/s$ occurs. (5 %)

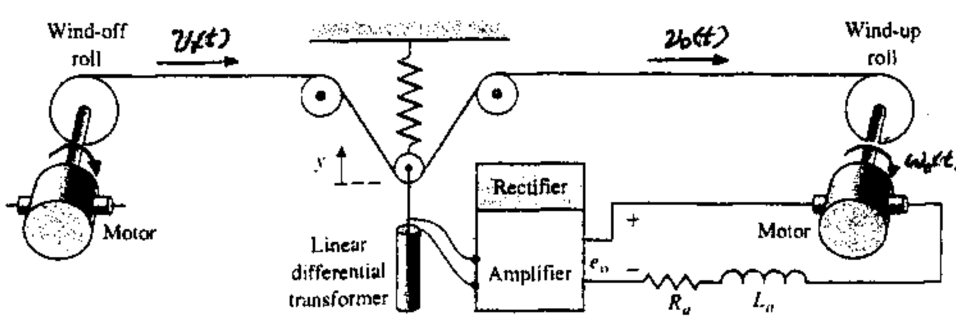


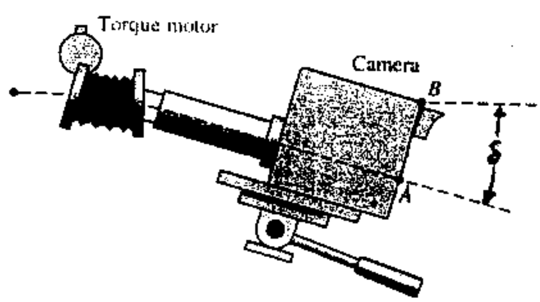
Fig. 2

3. An important problem for television system is the jumping or wobbling of the picture due to the movement of the camera. This effect occurs when the camera is mounted in a moving truck or airplane, The Dynalens system has been designed to reduce the effect of rapid scanning motion; see Fig.3. A maximum scanning motion of 25 % is expected. Let $K_g=K_t=1$ and assume that τ_g is negligible.

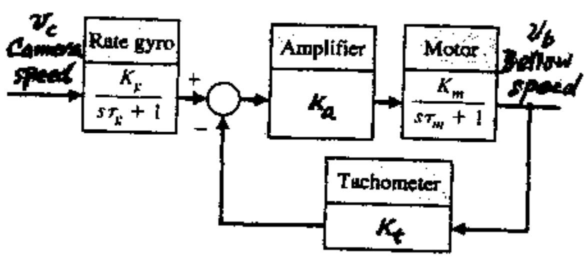
(a) Determine the error of the system E(s). (6 %)

(b) Determine the necessary loop gain, $K_a K_m K_t$, when a 1% steady state error is allowable. (7 %)

(c) The motor time constant is 0.40 sec. Determine the necessary loop gain so that the settling time to within 2 % of the final value of v_b is less than or equal to 0.03 sec. (7 %)



(a)



(b)

(6%)4. Consider a feedback control system sketched in Fig. 4.

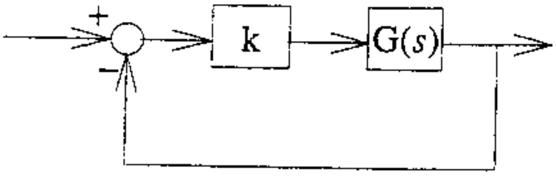


Fig. 4

$$G(s)=\frac{(S+a+jb)(S+a-jb)(S+c)}{S^5+2S^4+4S^3+6S^2+2S+8}\quad,\qquad a, b, c \in R$$

Find conditions to guarantee the stability of the feedback system for $k \to \infty$.

(17%)5. The block diagram of a feedback control system is shown in Fig. 5 (a). The transfer functions of the blocks are represented by the frequency response curves shown in Fig. 5 (b).

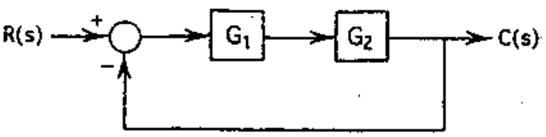


Fig. 5 (a)

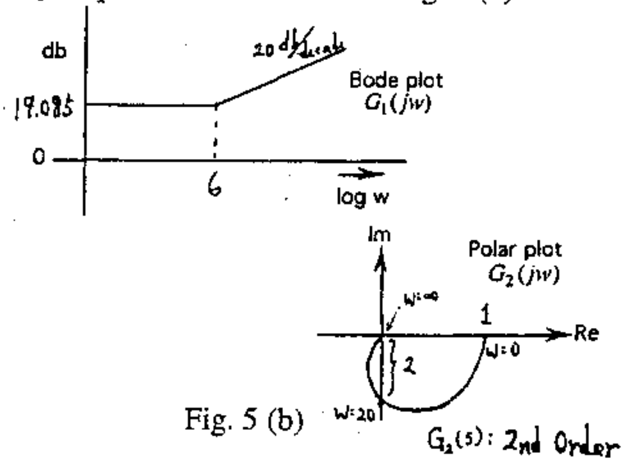


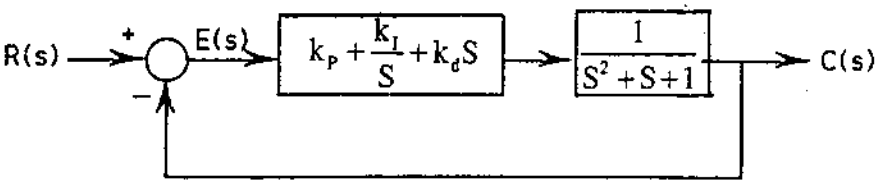
Fig. 5 (b)

a) Identify the transfer function of each block. (4%)

b) Plot the Bode diagram of $G_1G_2(jw)$. (8%)

c) Determine the phase and gain margins of the system. Is the system stable? (5%)

(11%)6. A second order plant is under a PID control.



a) (3%) Find the values for k_P, k_I and k_d to have the three closed loop poles at

$$\lambda_{C_1}=-2,\quad \lambda_{C_{2,3}}=-1\pm\sqrt{3}j$$

b) (8%) Let k_P and k_I be fixed to the values found in (a). Draw the root locus when the derivative control gain k_d is changed from 0 to ∞. (HINT: $(-1)^3+(-1)^2+8(-1)+8=0$)

(16%)7. Consider the four transfer functions given below.

(1)	(2)	(3)	(4)
$\dfrac{1}{S^2+a_1S+a_2}$	$\dfrac{1-TS}{1+TS}$	$\dfrac{e^{-SL}}{S}$	$\dfrac{S}{S^3+a_1S^3+a_2S^2+a_3}$
$a_1>0;\ a_2>0$	$T>0$	$L>0$	$a_1>0;\ a_2>0;\ a_3>0$

Select a frequency response sketch among those given below for each of the transfer functions.